Objectives and Incentives: Evidence from the Privatisation of Great Britain's Power Plants*

Thomas P. Triebs† Michael G. Pollitt‡

September 12, 2017

Does privatisation increase firm productivity because the private owner's objective is different, or because she is better able to control management? Is privatisation sufficient to improve productivity, or is it only effective in combination with competition? We answer these questions for Great Britain's electricity industry privatisation. We separate the effects of changes in objectives from changes in incentives by assuming, that the former only affect labour but not fuel productivity. And assuming that effective competition was only introduced after privatisation, we are able to separately identify the effects of privatisation and competition. We find that privatisation increased labour but not fuel productivity: evidence for the importance of objectives. There is some evidence that effective competition increased labour, but not fuel productivity. If there was an additional effect of competition, it was weak.

Keywords: privatisation, competition, productivity, electricity generation
JEL Classification No: L33, L22, L94

*We would like to thank the participants of the Mannheim Energy Conference 2017, EARIE Maastricht 2017, and the CEPE Seminar at the ETH Zurich for their comments and feedback. We would also like to thank Catherine Waddams, David Newbery, Paul Kattuman, Luis Orea Sanchez, David Saal, Justin Tumlinson, Oliver Falck, and Gerald Granderson for their valuable comments. Last, we would like to thank former research assistants as well several companies for helping with the data collection. The usual disclaimer applies.

†Corresponding author: School of Business and Economics, Loughborough University, LE11 3TU, UK, Email: t.triebs@lboro.ac.uk

‡Judge Business School and Energy Policy Research Group, University of Cambridge, Trumpington Street, Cambridge CB2 1AG, UK.

1. Introduction

Productive efficiency is an important driver of economic welfare (Leibenstein, 1966). And, theoretically, both private ownership and competition increase the productive efficiency of firms and plants. But there are alternative explanations for why privatisation increases productive efficiency. In this paper we empirically analyse whether privatisation increases firm productivity due to changed *objectives* or changed *incentives*. There is a related debate about whether privatisation itself increases productivity or whether privatisation increases productive efficiency only in combination with competition. We investigate whether the *combined* effect of privatisation and competition is different from the effect of privatisation only. Knowing why privatisation increases productive efficiency helps to predict the effect of actual privatisation and to mitigate any efficiency reducing effects of public ownership where public ownership is desirable for other reasons, e.g. curing market failures.

Assuming that both public and private owners have as their objective profit maximisation, private owners might be better able to solve the principal-agent problem where ownership and control are separate.[1] For private owners it might be easier to align their objectives with managers' objectives than for public owners, because public ownership is very diffuse (Shleifer, 1998) or because public owners are unable to apply hard budget constraints (Schmidt, 1996). Another strand of the theoretical literature assumes that public and private owners have different objectives for the firm. Public owners (and politicians in general) want to subsidise employment because workers vote. If the political cost of doing so is smaller for public than for private firms, privatisation increases (labour) productivity (Shleifer and Vishny, 1994; Boycko et al., 1996).

Our empirical setting is the privatisation of Great Britain's electricity generation plants. To test the relative importance of the *incentive* and the *objective* mechanisms we use the fact that the two major inputs into the short-run production function for electricity generation are fuel and labour. Our assumption is that the fuel input decision (unlike the labour input decision) at the plant level is independent of politics, i.e. burning extra fuel does not benefit any political constituency (ignoring miners). Finding an increase in labour but not fuel productivity, as we do, suggests that privatisation affects productivity via changes in objectives more than changes in incentives. There is previous evidence that ownership affects labour productivity more than fuel productivity. Although they do not discuss this result in their paper, Fabrizio et al. (2007) show that in the US publicly owned power plants have a lower labour, but similar fuel productivity, compared with investor-owned plants. Similarly, for nuclear generation plants, Pollitt (1996)

[1] We assume that ownership and control are separate for both public and private firms.

shows that whereas fuel productivity does not differ across ownership types, labour productivity is much higher for privately owned plants. Although Chinese reforms of the electricity industry are very gradual and somewhat opaque, the empirical evidence is that labour productivity increased much more than fuel productivity (Gao and Van Biesebroeck, 2014; Du et al., 2009).

Closest to our work is Gupta (2005) who empirically separates the incentive and objective effects assuming that partial (or cash flow) privatisation as opposed to full (or control right) privatisation can only possibly affect productivity via the incentive mechanism. She takes her finding that partial privatisations in India in the 1990s increased labour productivity, as evidence that the incentive mechanism matters. She also finds some suggestive evidence that full privatisation increased labour productivity further but due to data limitations is not able to test the effect of full privatisation formally. But unlike our natural experiment, hers does not allow for the possibility that only the objective mechanism matters. Her setting only allows the refutation of the incentive mechansism.

Principal-agent based arguments for why privatisation increases productivity are often similar to arguments for why competition increases productivity, which gives rise to a debate about whether privatisation itself increases productivity (as in Schmidt, 1996) or whether the effect of privatisation is conditional on environmental factors, in particular competition. In principal-agent settings the threat of bankruptcy (Schmidt, 1997), better information (Hart, 1983), or increased sensitivity of profits to managerial effort (Willig, 1987) can explain why competition increases productivity. Nickell (1996) summarizes these theoretical arguments. Empirically, there is evidence that competition increases the productive efficiency of firms and plants (Nickell, 1996; Galdón-Sánchez and Schmitz, 2002; Fabrizio et al., 2007). And, there is evidence that the effect of competition is more important than the effect of ownership (Caves and Christensen, 1980; Bartel and Harrison, 2005). We test whether the combined effect of *effective* competition and privatisation had an effect different from the effect of privatisation only. As effective competition was introduced only several years after privatisation (formally competition was introduced at privatisation) we assume that we capture the additional effect of competition rather than late effects of privatisation itself.

To study the effects of privatisation and competition on generation plant productivity we use the case of Great Britain's (GB) electric industry reforms: restructuring and privatisation (R&P) in 1990/1991 and subsequent competition reform in the second half of the 1990s. To our best knowledge, ours is the first study to analyse the causal effects of one of the UK's privatisation programmes at the plant-level. The GB case is of interest, because it was one

of the earliest and most pervasive utility industry reforms in the world.[2] An early reform focus on privatisation and a later focus on effective competition allow us to assess the relative importance of both reform steps. With the availability of comparable US plants as control group we can identify the effects using a standard difference-in-difference approach.[3] The cross-country comparison minimises the risk that treatment effects spill over to the control group. More generally, utility industries provide good cases to test the above theoretical predictions. The technology (here electricity generation from coal) is fairly simple, has inputs and outputs that are homogeneous and easy to measure in physical units, is globally available, and fairly constant over time. The short-run substitution patterns of the technology allow us to analyse productivity changes for labour and fuel separately, which is crucial for our strategy to separate the objective and incentive mechanisms.[4] Third, most plants in the treatment group continue, which is crucial for any incentive effect not being due to selection (Syverson, 2004).

Our empirical approach is to model plant level productivity as a set of input demand functions derived from a model of constraint cost minimisation (Biesebroeck, 2003). Despite the treatment being at a more aggregate level, plant-level data is useful. Aggregate data on input and outputs does not allow the measurement of aggregate labour and fuel input for a specific fuel type only. Also, with aggregate data we could not control for selection using plant fixed effects. One disadvantage of plant level data is that output is potentially endogenous to unobserved shocks. Therefore, we use aggregate sales interacted with region indicators as an instrument for plant output. We collected unique plant-level input-output data for a sample GB electricity generation plants for the years 1981 to 2004 and matched it with an extended version of the data used by Fabrizio et al. (2007) for US, publicly owned plants.

We find that privatisation increased labour productivity by about 50 per cent, but it did not increase fuel productivity. This is evidence, that privatisation improved productivity via changes in objectives rather than incentives. There is some evidence that the introduction of effective competition had an additional effect on labour but not fuel productivity. Competition,

[2]For an overview of the reform literature see Pollitt (2012)

[3]There is a large literature comparing the cross-sectional performance between public and private firms. For instance, Pollitt (1995) finds no productivity difference. Arocena and Waddams Price (2002) find that the productivity difference depends on the type of regulation. Then there is a large literature making before-after comparisons. D'souza and Megginson (1999) find that operating efficiency increased for a sample of 85 privatisations across developed and developing countries, over the years 1990 to 1996. They find employment reductions only for firms in developed countries. Waddams Price and Weyman-Jones (1996) show that productivity growth increased after the privatisation of the British gas industry but that more effective competition would have produced even bigger benefits. Newbery and Pollitt (1997), using a simulated counterfactual showed that the privatisation of the UK's electricity industry increased welfare and that technical efficiency gains were larger than allocative efficiency gains.

[4]Following Fabrizio et al. (2007) and others we assume that incentives can affect labour and fuel productivity in the short-run.

if it had an effect at all, had a much smaller effect than privatisation.

The outline is as follows. Section 2 provides some background information on GB electricity R&P. Section 3 describes our empirical approach. Section 4 describes the data. Section 5 gives the results and section 6 concludes.

2. Background

Before R&P in 1991, the generation and transmission of electricity in England & Wales was the responsibility of the Central Electricity Generation Board (CEGB), a horizontally and vertically integrated state-owned monopoly. Distribution in England & Wales was the responsibility of 12 regional monopolies, the Area Boards. In Scotland and Northern Ireland vertically integrated, regional monopolies were responsible for generation, transmission, and distribution.[5] Even though the Scottish reform process was slightly different, we include Scottish plants in this study. Northern Irish plants are excluded, because Northern Ireland was not interconnected with Great Britain during our sample period.

A first attempt to liberalise the market was undertaken in 1983 when the Energy Act required the Area Boards to buy energy from independent (non-CGEB) generators at avoided cost. As the Act did not protect entrants from anti-competitive behaviour by the incumbent the reform was ineffective (Vickers et al., 1991). Eventually, the restructuring of the industry in England and Wales began in March 1988 and was completed in March 1990. The industry was privatised the following year in March 1991. In Scotland the industry was also privatised in 1991 but was not restructured immediately.[6] Restructuring in England and Wales comprised the vertical unbundling of generation and transmission as well as the horizontal separation of generation.[7] Generation assets were separated into four companies: all fossil-fuel plants were divided between PowerGen and National Power (our sample), the new transmission company National Grid obtained pumped storage plants, and Nuclear Electric the nuclear plants. Sixty percent of the shares in PowerGen and National Power were sold to the public in 1991. The remaining shares were sold in February 1995. There is no evidence that the government retained control after 1991, but continued government ownership might have created a conflict of interest in relation to competition. Part of Nuclear Electric was only privatised in 1996 (as British Energy) and is not included in this study. The Area Boards and the transmission company became private,

[5] Whereas Scotland had two companies, Northern Ireland only had a single electricity company.

[6] See Pollitt (1997) and Pollitt (1999) for a discussion of the Northern Irish and Scottish cases, respectively.

[7] In the US restructuring often refers to the introduction of competition, i.e. market liberalisation.

regulated monopolies.

Even though a deregulated wholesale market was established at R&P, competition among electricity generators was not effective, because National Power and PowerGen formed a duopoly for fossil-fuel generation (Sweeting, 2007). Government gave the newly created firms market power to maximise the proceeds from privatisation (Henney, 2010, p. 37). Moreover, the rules of the newly established wholesale market, referred to as the Pool, facilitated the exercise of market power (Green, 2006). Also, at R&P only sales to industrial customers (above 10 MW) were deregulated, partly to burden retail customers with the high cost of British coal, which plants were committed to buy. Prices for smaller customers were deregulated in stages until retail was fully deregulated in 1999.

A few years after R&P, high electricity prices and profits shifted political attention from ownership to competition. As a first measure the regulator capped wholesale prices between 1994 to 1996. Then, in 1996 and 1999 incumbents divested plants to competitors. There is evidence that only the second round changed firm behaviour. In the first round plants were leased to a single competitor and lease contracts were such that the new owner had no incentive to compete (Henney, 2010, p. 37). Sweeting (2007) provides evidence that firms (tacitly) colluded throughout the second half of the 1990s. In 1999 the incumbents sold plants to various (mostly US) investors in return for regulatory permission to vertically integrate with the supply function. For example, Edison Mission bought two plants in 1999 and increased output by 30% (Newbery, 2004, p. 18), which is unlikely to be the result of efficiency increases alone. Probably, the entry of US firms in the late 1990s ended tacit collusion between the generators. Overall, market concentration for generation decreased considerably throughout the 1990s. The Herfindahl Hirschman index, a measure of market concentration, for coal fired plant had dropped by 1999 to a fifth of its value in 1991.

Given this reform history we choose as the privatisation date the year 1991 and we choose 1999 as the date for the introduction of (effective) competition. It seems probable that the introduction of full retail competition and plant divestitures in 1999 were more important for competition than the measures taken before. However, we also test 1996, the year of the first divestiture round, as an alternative date for the introduction of effective competition.

3. Empirical Model and Identification

The empirical analysis of productivity change requires a model of the production technology. We apply the model developed by Biesebroeck (2003) and Fabrizio et al. (2007), because it represents accurately the short-run production function of an electricity generation plant. In

particular, it models the temporal sequence of input decisions and the resulting constraints on short-run input substitution.

We model actual production as the minimum of planned (or "probable") output Q^P, which is a function of capital and labour, and fuel input $g(\cdot)$. Actual output (observed by the researcher) could be more or less than planned output, depending on differences between actual and expected demand as well as unexpected changes in plant availability. Actual output Q^A for plant i in year t takes the following Leontief form:

$$Q_{it}^A = \min[g\left(E_{it}, \Gamma^E, \epsilon_{it}^E\right), Q_{it}^P\left(K_i, L_{it}, \Gamma^P, \epsilon_{it}^P\right)\exp\left(\epsilon_{it}^A\right)]. \quad (1)$$

Γ denotes coefficient vectors and ϵ represents error terms. If planned output is not constrained, $Q^A = Q^P \exp\left(\epsilon_{it}^A\right)$, i.e. actual output equals probable output multiplied by a shock that is observed by the plant manager at the time of actual production. ϵ_{it}^P is observed by the plant manager but at the time of planning. As errors are not observed by the researcher we have to take into account simultaneity bias. Planned output is a function of capital K and labour L, but capital is treated as fixed to reflect the short-run nature of the production function. Planned output is not a function of fuel, because the amount of fuel is determined by actual output. Intuitively, whereas the amounts of non-fuel inputs are chosen before production takes place fuel input depends on actual production. For us the crucial property of this production function is that it does not allow labour to substitute for fuel in the short-run. Also, neither in the medium nor the short-run can the plant manager substitute labour for capital. Next, we derive the demands for labour and fuel.

We derive labour demand assuming cost minimisation behaviour constrained by a Cobb-Douglas production function for probable output $Q_{it}^P = Q_0(K_i) L_{it}^{\rho} exp\left(\epsilon_{it}^P\right)$. Again, capital is fixed. Given a short-run objective function that minimises labour cost, $\min W_{it} \times L_{it}$, we can derive the following labour demand equation:

$$\ln L_{it} = \alpha_0 + \ln Q_{it}^A - \ln W_{it} - \epsilon_{it}^A, \quad (2)$$

where labour L is a function of actual output Q^A, the wage W, and a constant $\alpha_0 = \ln(\lambda\rho)$, which has two components: the Lagrangian multiplier or shadow value of changes in the output constraint λ and the labour parameter ρ or marginal productivity from the production function. In the empirical specification a number of proxies control for λ and the change in ρ is captured by the treatment indicator.

The derivation of the fuel demand follows a different strategy as the fuel input is not part of the optimisation problem used to derive the demand for labour. We only need to assume that $g(\cdot)$ is monotonically increasing in fuel E and inversion produces the following fuel demand equation:

$$\ln E_{it} = \gamma_Q \ln Q_{it}^A + \epsilon_{it}^E \,, \tag{3}$$

where γ is the output coefficient. Unlike for labour the fuel demand function does not depend on input price. As plants are scheduled by a central planner before actual production, actual production does not depend on the price of fuel, only the schedule (or merit order) does.

We need to expand these theoretical demand equations by a set of indicator variables to identify the difference in the productivity change between treated and non-treated plants from before treatment to after treatment. First, we add plant fixed effects α_i to control for any cross-sectional differences across plants like weather, technology, or time-invariant differences in regulatory regimes. Second, we add year fixed effects α_t to control for technological progress for all plants. Finally, we use two indicators for treatment: δ^P indicates if the plant is privatised, i.e. the indicator takes the value one if the plant is in GB after 1991 and before 1999 (alternatively 1996), δ^C indicates if the plant is privatised *and* exposed to effective competition, i.e. the indicator takes the value one if the plant is in GB after 1999 (or alternatively 1996). To the extent that the effect of privatisation is time-invariant, δ^C captures the effect of privatisation and competition. And the difference between δ^C and δ^P captures the effect of competition only. If the effect of privatisation was not time-invariant but increased over time, δ^C would overestimate the true effect of competition. To investigate whether the treatment effects are likely to be time-invariant (and whether there is anticipation) we also estimate a version of the model where we replace δ^P and δ^C by a set of indicators for each year from 1985 to 2004.[8] The disadvantage of this model is that the indicators also capture year specific shocks in GB that are unrelated to the treatments. To make our standard errors robust to unobserved, persistent productivity shocks we follow Bertrand et al. (2004) and cluster errors at the treatment level, i.e. the clusters are US states or GB.

The fixed effects also control for the time-invariant part of the unobserved output constraint λ. Additionally, we add several observables. We include a variable for plant age (AGE). Joskow and Schmalensee (1987) found that plant performance "deteriorates significantly" with age. However, Hiebert (2002) showed that length of service might actually increase performance as

[8]Note we can only investigate anticipation for privatisation, because for the competition treatment we cannot tell apart the effect of privatisation and anticipation of the competition effect.

plant management learns to better operate the plant. Pollitt (1995, p. 132) found no significant age effect for a sample of base load plants. We control for capital using net capacity (CAP) and the presence of SO2 abatement technology (FGD). We also control for load factor (LF), as the scale at which a plant operates affects productivity. After R&P plants might have been called upon in a different order (their position in the merit order changed), which would affect performance (Knittel, 2002). The load factor might also control for different operating patterns. Bushnell and Wolfram (2005, p. 2) state that "irregular operating patterns motivated by attempts to exercise market power and the disruption of an ownership change could diminish operating efficiency at least in the short-run". The reduced form labour demand equation is

$$\begin{aligned} \ln L_{igt} &= \alpha_i + \alpha_t + \delta_{it}^P + \delta_{it}^C + \beta_1^N \ln NET\,GWH_{igt} + \beta_2 \ln W_{it} \\ &+ \beta_3 FGD_{it} + \beta_4 AGE_{it} + \beta_5 LF_{it} + \beta_6 \ln CAP_{it} + e_{it}\,, \end{aligned} \tag{4}$$

where the error term e combines the deviation from planned output ϵ^A and an input specific error ϵ^L. The reduced form for fuel (not shown) is identical but omits the input price variable. As we do not observe all the variables for all the plants, in particular, we have fewer observations for labour, we effectively estimate the two input demands for different samples. But we have no reason to believe that plants strategically under-reported labour input this should make no difference.

Due to unobserved productivity shocks output is probably not exogenous. Following Fabrizio et al. (2007) we use aggregate sales, a demand proxy, as an instrument for plant output. But as we have no regional sales figures for GB (and the first stage is not statistically significant for sales) we interact sales with a region indicator (US states or UK regions). For the US we extend the Energy Information Agency's series for state level sales used by Fabrizio et al. (2007). For GB we use the final electricity consumption series from the National Statistics' "Energy consumption in the United Kingdom" publication. Our IV estimator is a two-stage least squares within estimator.

4. Data and Summary Statistics

4.1. Great Britain

We collected generation plant data for physical inputs and outputs from various sources. First, we collected all data that is publicly available, e.g. from industry statistical yearbooks, firm reports, government. Second, we contacted firms directly to obtain additional data. The amount

of fuel input is not always observed directly. For the years before privatisation we derive fuel input from output and plant specific efficiency factors, which are reported in the CEGB yearbooks. After privatisation we sometimes observe CO2 emissions but not fuel input. As CO2 emissions at the plant level are calculated from fuel samples we use emissions to measure fuel input wherever it is not observed directly (for details see section B in the Appendix). Also, we replace missing values for fuel type and capacity with adjacent values in time, assuming that they do not change much over time.

For the labour input demand equation we also derive missing plant-level output from capacity and fuel specific efficiency factors (for details see section B in the Appendix). The relevant assumption that labour input does not change with output on a year-by-year is reasonable. For GB's largest coal fired plant we only observe the average labour input before privatisation. As it is valuable to include the largest plant in our sample, we assume that for the years before privatisation its labour input was constant. Finally, listwise deletion by input reduces the number of observations considerably. For fuel, we have no observations for years 1988 to 1991, the years of restructuring and privatisation, because the CEGB did not publish statistical yearbooks in this period. Thus, we cannot say that the missing values are entirely random in the time-series, but we have no reason to believe that the same is true for the cross-section. The resulting sample is an unbalanced panel with gaps for the years 1981 and 2004. For GB and the US we have a total of 1923 plant-year observations for the fuel demand equation and 1718 for the labour demand equation. For fuel about 25 per cent of the observations are for GB, for labour it is about 15 per cent. We restrict our sample to coal fired plants to maximise comparability over time and across the two countries. All variables and their measurements are listed in Table 1.

Some variables are corrected. Whereas some firms report for financial years others report for calendar years. We correct for this by constructing calendar year data from the weighted financial year data (weights are simply the number of months). We drop observations just after a plant is installed or just before it is shut down, because in these years plants do not operate regularly. We measure the presence of FGD by plant level dummies. Plants typically consist of several units and the fitting of abatement technology typically occurs over several years, unit by unit. The FGD dummy takes the value 1 if the first unit is fitted.

Wage data is not available at the plant level. We take gross, weekly, regional wages from the New Earnings Survey (published by the UK Office for National Statistics). As the series only goes back to 1986 we use linear extrapolation to fill the gaps to 1981.

Table 1: Variables and Measurement

Variable	Definition
Fuel	Mtce/year
Labour	number of employees/year
Output	net GWh/year
Capacity	net MW
FGD	1 if FGD fitted; 0 otherwise
Age	number of years since first unit commissioned
Load factor	Proportion
Wage	regional, gross, weekly, pounds at market exchanges rates
POSTX	structural break indicator: 1 if year $>$ X and country==GB; 0 otherwise

4.2. United States

For the US, we start with the data used by Fabrizio et al. (2007) which is available as an online appendix to their paper. As our control group we use cooperatively and publicly (municipal or federal) owned plants in both restructuring and non-restructuring states. According to Fabrizio et al. (2007, p. 1259) US restructuring did not change the competitive environment for public utilities, except in Arizona and Arkansas which we exclude. We then extend their data to 2004 using commercially available data from Platts. We also extend all other variables using publicly available data. We extend the wage data using the Bureau of Labor Statistics' Quarterly Census of Employment and Wages series. Doing so we have to deal with the change from the SIC to the NAICS industry classification system. The original series is for SIC 4911 (Electric Services). We extend it using NAICS 221112 (Fossil Fuel Electric Power Generation).

Table 2 compares the means between GB and the US plants. In terms of capacity GB plants are about 50 per cent larger than US plants but have a 10 percentage points lower load factor. Plants have almost the same vintage. Wages are about double in the US (at market exchange rates). The average plant in the UK is quite different from the average plant in the US but for our comparison to be valid we only require that the productivity trends, in the absence of the treatment, are identical.

Table 2: Comparison of Means

	Means		t-stat. for diff.
	US	GB	S.E.
Fuel (mtce)	1.53	2.08	0.55***
			(0.09)
Output (net GWh)	4114.60	5282.40	1167.80***
			(209.12)
Capacity (net MW)	800.34	1172.09	371.74***
			(37.05)
Load factor	0.57	0.47	−0.10***
			(0.01)
Wage (gross weekly)	475.89	229.80	−246.09***
			(7.87)
Age (years)	23.44	23.56	0.12
			(0.65)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

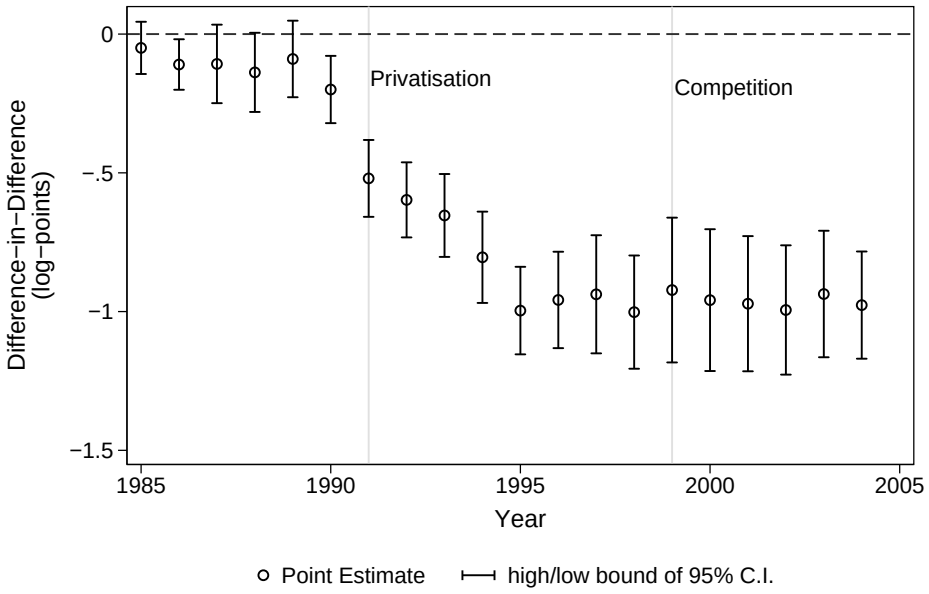
5. Results

To begin, we investigate whether the effect of privatisation was anticipated and whether the effects of privatisation and competition were constant after treatment. The model uses a set of indicators, one for each year after privatisation as well as for several years before. Figure 1 plots the estimated yearly difference-in-difference effects in log-points and their 95 percent confidence intervals. A negative (positive) estimate indicates a productivity increase (decrease) in GB relative to the US. The two vertical lines indicate the treatment dates. In the upper panel we see that GB's labour productivity did not increase before privatisation, suggesting it was not anticipated. Our difference-in-difference identification strategy requires the assumption that absent treatment, both the treatment and control groups follow a common trend. As usual this cannot be tested, because the true counterfactual is unobserved. But the statistically insignificant leads indicate that the assumption is reasonable.[9] Then, GB's labour productivity increased strongly at privatisation in 1991. Even though the initial effect was large the effect continued to grow until 1995, after which the effect was stable until the end of our sample. It seems that the introduction of effective competition in 1999 (or in 1996) had no additional effect on labour productivity.

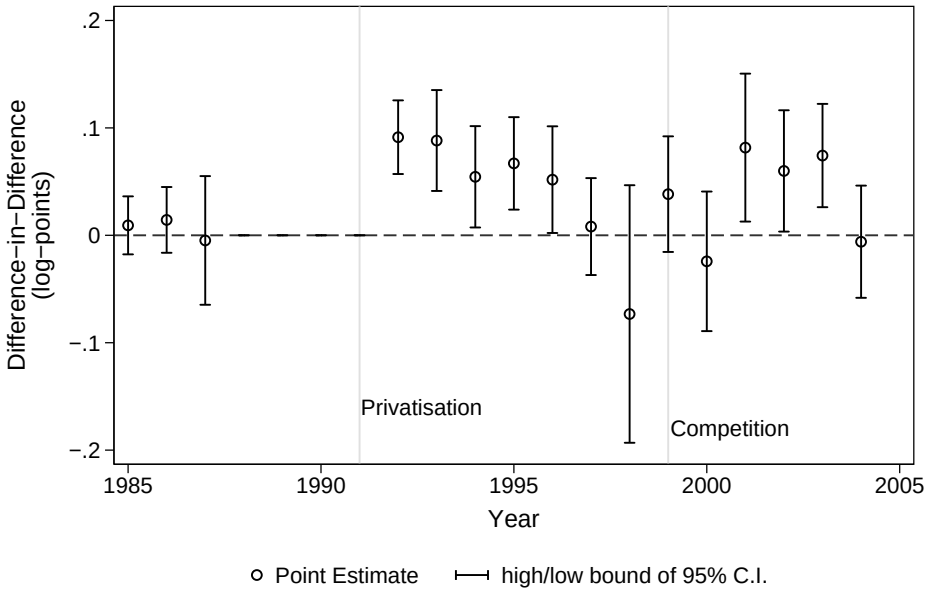
The bottom panel shows that also for fuel there were no significant effects before privatisation.

[9]These findings also corroborate the common trends assumption made by Newbery and Pollitt (1997).

Remember we have no observations for GB for the years 1988 to 1991. We see that after privatisation fuel productivity in GB actually decreased, but caught-up again with the US trend around 1997. Like for labour, it seems that the introduction of effective competition in 1999 (or 1996) did not increase fuel productivity. This model with year-on-year effects is very flexible but has the disadvantage that the treatment indicators also capture other year-specific events in GB. Especially for fuel productivity, which is more likely to be affected by year-specific shocks this is a problem.



(a) Labour



(b) Fuel

Figure 1: Trend comparison

Notes: The graphs plot the coefficient estimates and their 95% confidence intervals for year-on-year difference-in-difference indicators. Great Britain is the treatment group and the United States is the control group. A positive (negative) estimate represents a decrease (increase) in productivity. The two vertical lines gives the dates for privatisation and the introduction of competition in Great Britain. The missing estimates for fuel are due to gaps in the data.

Therefore, our preferred model is (4) (and the equivalent for fuel), which averages the effects within the two treatment regimes: privatisation from 1991 to 1999 (or 1996) and privatisation

and competition from 1999 (or 1996) until the end of our sample. This effectively constrains the effects to be constant within regimes and provides estimates that are robust to annual, GB-specific events. Table 3 gives the regression results for these regime average effects, where the coefficient estimates for δ^P (the productivity level shift due to privatisation) and δ^C (the productivity level shift due to competition) are POST1991 and POST1999, respectively. The first two columns give the OLS and IV estimates for labour. The last two columns give the same estimates for fuel. As we estimate input demands, a positive (negative) intercept change implies a decrease (increase) in average input productivity. For both inputs, the first stage F-statistics are extremely high, which is probably due to the fact that aggregate sales are interacted with region indicators leading to a large number of instruments.[10] For labour, the output coefficient is statistically not different from zero for both OLS and IV. For fuel, the IV estimate is higher than the OLS estimate, implying a negative correlation between unobserved productivity shocks and fuel input. For instance, during an output reducing plant break down, more fuel might be required. Overall, the estimates for the treatment effects do not vary much between the OLS and IV estimators.

Using the approximation $[\exp(\delta) - 1] \times 100$ we see that privatisation increased labour productivity by about 46 per cent but *decreased* fuel productivity by about 4.7 per cent (for the OLS estimate). The actual decrease in fuel productivity might be explained by a loss of economies of scope after restructuring. Alternatively, it might be explained by market power being higher after privatisation, that is despite the introduction of formal competition, incentives might have been weaker than under public ownership. The labour productivity effect is large but consistent with firm aggregate data (Newbery and Pollitt, 1997, Table 1). Nevertheless, it is likely to overestimate the true effect of privatisation, because our measure of head count does not take into account changes in working hours or outsourcing. Assuming that a change in objectives does not affect fuel productivity, the combination of the positive effect for labour productivity and the negative effect for fuel productivity is evidence that privatisation affected productivity through changes in objectives rather than incentives. Before privatisation the public owner over-staffed power plants not because she was unable to monitor and incentivise management, but because it was politically beneficial to do so. Thus, unlike Gupta (2005) for Indian privatisations, we find no evidence that privatisation increased productivity through better incentives. Contrasting the results suggests that in GB public owners controlled and supervised management effectively. This interpretation is supported by anecdotal evidence. For instance, in GB the public owner encouraged fuel productivity through a culture that valued engineering excel-

[10] We have 25 US states and 12 GB regions.

Table 3: The effects of privatisation and competition

	ln(Labour)		ln(Fuel)	
	OLS	IV	OLS	IV
ln(NET GWH)	0.006	−0.452	0.927***	0.959***
	[0.93]	[0.23]	[0.00]	[0.00]
ln(CAP)	0.621***	1.131**	−0.030	−0.069
	[0.00]	[0.01]	[0.70]	[0.59]
LF	0.504***	1.646	−0.049	−0.134
	[0.00]	[0.07]	[0.39]	[0.64]
AGE	0.007	0.007	−0.017**	−0.017**
	[0.53]	[0.55]	[0.01]	[0.00]
ln(WAGE)	−0.111	−0.133		
	[0.16]	[0.05]		
FGD	−0.040	0.003	0.032*	0.030*
	[0.64]	[0.97]	[0.02]	[0.04]
POST1991	−0.622***	−0.631***	0.046*	0.045*
	[0.00]	[0.00]	[0.01]	[0.01]
POST1999	−0.706***	−0.620***	0.047*	0.040
	[0.00]	[0.00]	[0.04]	[0.16]
Constant	2.287	1.377	−6.822***	−6.808***
	[0.12]	[0.17]	[0.00]	[0.00]
N	1718	1718	1923	1923
DV Mean	5.14	5.14	0.06	0.06
Plant FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
1st st. F		541440.53		613810.52
R^2	0.95		0.99	

p-values in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is the log of labour or fuel input. The IV estimator is 2-stage least squares within. The estimates for POST1991 and POST1999 are the treatment effects for privatisation and competition respectively. Standard errors are clustered at the treatment level (US states and GB).

lence (Newbery, 1995). Also, the publication of statistical industry yearbooks, made it easy to benchmark plant performance. Actually, there was less transparency after privatisation.

What was the additional effect of the introduction of effective competition in 1999? As there is no theoretical reason why competition should affect labour and fuel differently we look at both input productivities. Whereas the OLS estimates for POST1999 are slightly larger than the estimates for POST1991, suggesting an additional effect of competition, the IV estimates are smaller for both inputs. Thus overall, there is no evidence that competition increased productivity. Even when looking at the OLS estimates only, competition increased productivity by an additional 3 and 1 per cent for labour and fuel, respectively. In absolute terms privatisation had a much larger impact. But remember that it is not obvious when exactly competition in the GB market became effective. It might be, that we date the onset of effective competition too late, and attribute the competition effect to privatisation. Table 4 in the Appendix gives the results for the assumption that effective competition was introduced already in 1996. There is still no evidence that competition increased labour *and* fuel productivity. However, now there is evidence that competition increased labour productivity by between 3 and 7 per cent, depending on the estimator. These effects are similar to the 6 per cent effect found by Fabrizio et al. (2007). The effect shows that even though privatisation increased productivity it did not make plants fully productive. Competition, through better incentives, increased productivity further. Looking at fuel productivity we see that the onset of competition reversed the productivity decrease after privatisation. But we do not consider this to be evidence for a positive effect of competition, because there was no actual increase in productivity compared to the control group (consistent with the findings of Fabrizio et al. (2007) for the US).

To conclude, we found strong evidence that privatisation increased productivity due to a change in objectives not incentives. We found no evidence that competition increased labour *and* fuel productivity as it should theoretically. But, depending on when we assume competition became effective, there is evidence that competition increased labour productivity.

6. Conclusion

This article contributes to the small literature on the causal effects of privatisation and competition on plant-level productivity. Also, our quasi-experiment, the privatisation of Great Britain's power plants, allows us to ask whether privatisation increases productivity due to changed objectives or incentives. And it also allows us to separate the effects of privatisation and competition. One explanation for the productivity enhancing effect of privatisation is that the public owners' objective is not profit maximisation. As labour, unlike other inputs, votes,

it is often politically beneficial for public owners to over-staff plants, thereby reducing labour productivity. An alternative explanation is that private owners are better able to solve the principal-agent problem when ownership and management are separate. Related to the debate about which of these explanations matters most, is a debate about whether privatisation increases productivity absent competition or not. Some, but not all, of the theoretical arguments why privatisation improves incentives rely on privatisation coinciding with the introduction of competition. It is then competition that actually allows private owners to improve control over management. We ask whether in GB the introduction of effective competition after privatisation had an additional effect on productivity.

To separate the *incentive* from the *objective* effect we assume that labour and fuel productivities respond differently depending on the mechanism at play. Whereas public owners derive little political benefit from subsidizing fuel at the plant level, the benefit derived from surplus employment in terms of votes might be considerable. The objective mechanism predicts that privatisation only increases labour productivity whereas the incentive mechanisms predicts that it improves both labour and fuel productivity. To separate the privatisation effect from the competition effect we assume that, even though a market for electricity was established at privatisation, *effective* competition was introduced only after privatisation. A complication in separating the two events is that although we can precisely date privatisation we cannot do so for the introduction of effective competition. We check whether the results are robust to alternative dates. We collected unique data for plant level inputs and outputs and matched it with data for comparable US plants. The data allows us to apply fixed effects or difference-in-difference estimation to identify causal effects.

We find that privatisation increased labour productivity by about 50 per cent but actually decreased fuel productivity by around 4 per cent. Together, these changes are evidence that privatisation increased productivity, because it changed owner's objectives, not because private owners are better able to control management. Our finding that the objective mechanism dominates, contrasts with the finding of Gupta (2005) that incentives matter most. We suggest that the difference is due to the fact that public owners vary in their ability to overcome the principal-agent problem. In contrast to some of the previous studies of privatisation (Caves and Christensen, 1980; Bartel and Harrison, 2005) we find that the privatisation effect is much larger than the competition effect. We find that the introduction of effective competition several years after privatisation increased labour but not fuel productivity. Even though this result is consistent with the empirical evidence for US restructuring (Fabrizio et al., 2007), the theory on the incentive mechanism does not make differential predictions for different outputs. Note that

as fuel productivity changed at privatisation, it is unlikley that this result is due to the fact that fuel productiviy cannot respond in the short-run. To conclude, we find strong evidence that privatisation increases productivity due to changes in objectives, rather than incentives. We find no evidence for the theoretical prediction that competition increases all input productivities. If we apply the prediction that competition increases productivity to labour only we find that privatisation increases productivity, but only competition makes plants fully efficient.

References

Arocena, P. and Waddams Price, C. (2002). Generating efficiency: economic and environmental regulation of public and private electricity generators in Spain. *International Journal of Industrial Organization*, 20:41–69. 1.

Bartel, A. P. and Harrison, A. E. (2005). Ownership versus environment: Disentangling the sources of public-sector inefficiency. *Review of Economics and Statistics*, 87(1):135–147.

Bertrand, M., Duflo, E., and Mullainathan, S. (2004). How Much Should We Trust Differences-In-Differences Estimates? *The Quarterly Journal of Economics*, 119(1):249–275.

Biesebroeck, J. v. (2003). Productivity Dynamics with Technology Choice: An Application to Automobile Assembly. *The Review of Economic Studies*, 70(1):167–198.

Boycko, M., Shleifer, A., and Vishny, R. W. (1996). A Theory of Privatisation. *The Economic Journal*, 106(435):309–319.

Bushnell, J. B. and Wolfram, C. D. (2005). Ownership change, incentives and plant efficiency: The divestiture of US electric generation plants. *Center for the Study of Energy Markets Paper CSEMWP-140*.

Caves, D. W. and Christensen, L. R. (1980). The Relative Efficiency of Public and Private Firms in a Competitive Environment: The Case of Canadian Railroads. *Journal of Political Economy*, 88(5):958–976.

D'souza, J. and Megginson, W. L. (1999). The Financial and Operating Performance of Privatized Firms during the 1990s. *The Journal of Finance*, 54(4):1397–1438.

Du, L., Mao, J., and Shi, J. (2009). Assessing the impact of regulatory reforms on China's electricity generation industry. *Energy Policy*, 37(2):712–720.

Fabrizio, K. R., Rose, N., and Wolfram, C. D. (2007). Does Competition Reduce Cost? Assessing the Impact of Regulatory Restructuring on U.S. Electric Generation Efficiency. *American Economic Review*, 97:1250–1277. 4.

Galdón-Sánchez, J. E. and Schmitz, Jr., J. A. (2002). Competitive Pressure and Labor Productivity: World Iron-Ore Markets in the 1980's. *American Economic Review*, 92:1222–1235. 4.

Gao, H. and Van Biesebroeck, J. (2014). Effects of Deregulation and Vertical Unbundling on the Performance of China's Electricity Generation Sector. *The Journal of Industrial Economics*, 62(1):41–76.

Green, R. (2006). Market power mitigation in the UK power market. *Utilities Policy*, 14(2):76–89.

Gupta, N. (2005). Partial privatization and firm performance. *The Journal of Finance*, 60(2):987–1015.

Hart, O. D. (1983). The market mechanism as an incentive scheme. *The Bell Journal of Economics*, pages 366–382.

Henney, A. (2010). *The British Electric Industry, 1990-2010: The Rise and Demise of Competition*. EEE Limited, London.

Hiebert, L. D. (2002). The Determinants of the Cost Efficiency of Electric Generating Plants: A Stochastic Frontier Approach. *Southern Economic Journal*, 68:935–946. 4.

Joskow, P. L. and Schmalensee, R. (1987). The Performance of Coal-Burning Electric Generating Units in the United States: 1960–1980. *Journal of Applied Economics*, 2:85–109. 2.

Knittel, C. R. (2002). Alternative Regulatory Methods and Firm Efficiency: Stochastic Frontier Evidence from the U.S. Electricity Industry. *The Review of Economics and Statistics*, 84:530–540.

Leibenstein, H. (1966). Allocative Efficiency vs. 'X-Efficiency'. *The American Economic Review*, 56(3):392–415.

Newbery, D. M. (1995). Notes from visit to Drax. In *personal communication*, Cambridge.

Newbery, D. M. (2004). Electricity liberalisation in Britain: the quest for a satisfactory wholesale market design. *CMI Working Paper Series*, 64.

Newbery, D. M. and Pollitt, M. G. (1997). The Restructuring and Privatisation of Britain's CEGB–Was It Worth It? *The Journal of Industrial Economics*, 45(3):269–303.

Nickell, S. J. (1996). Competition and Corporate Performance. *Journal of Political Economy*, 104:724–746. 4.

Pollitt, M. G. (1995). *Ownership and Performance in Electric Utilities*. Oxford University Press, Oxford-New York.

Pollitt, M. G. (1996). Ownership and efficiency in nuclear power production. *Oxford Economic Papers*, 48(2):342–360.

Pollitt, M. G. (1997). The restructuring and privatisation of the Electricity Supply Industry in Northern Ireland - will it be worth it? *DAE Working Paper, University of Cambridge*, No 9701.

Pollitt, M. G. (1999). The restructuring and privatization of the Electricity Supply Industry in Scotland. *Cambridge University, Department of Applied Economics, mimeo.*

Pollitt, M. G. (2012). The role of policy in energy transitions: Lessons from the energy liberalisation era. *Energy Policy*, 50:128–137.

Schmidt, K. M. (1996). The Costs and Benefits of Privatization: An Incomplete Contracts Approach. *Journal of Law, Economics, and Organization*, 12(1):1–24.

Schmidt, K. M. (1997). Managerial Incentives and Product Market Competition. *The Review of Economic Studies*, 64(2):191–213.

Shleifer, A. (1998). State versus Private Ownership. *Journal of Economic Perspectives*, 12(4):133–150.

Shleifer, A. and Vishny, R. W. (1994). Politicians and firms. *The Quarterly Journal of Economics*, pages 995–1025.

Sweeting, A. (2007). Market Power In The England And Wales Wholesale Electricity Market 1995–2000. *The Economic Journal*, 117(520):654–685.

Syverson, C. (2004). Market Structure and Productivity: A Concrete Example. *Journal of Political Economy*, 112(6):1181–1222.

Vickers, J., Yarrow, G., Rochet, J.-C., and Venables, A. (1991). The British Electricity Experiment. *Economic Policy*, 6(12):187–232.

Waddams Price, C. and Weyman-Jones, T. (1996). Malmquist indices of productivity change in the UK Gas industry before and after privatization. *Applied Economics*, 28:29–39.

Willig, R. D. (1987). Corporate Governance and Market Structure. In Razin, A. and Sadka, E., editors, *Economic Policy in Theory and Practice*, pages 481–503. Palgrave Macmillan UK.

A. Tables

Table 4: The effects of privatisation and competition

	ln(Labour)		ln(Fuel)	
	OLS	IV	OLS	IV
ln(NET GWH)	0.008	−0.310	0.934***	0.959***
	[0.90]	[0.43]	[0.00]	[0.00]
ln(CAP)	0.643***	1.001*	−0.054	−0.083
	[0.00]	[0.02]	[0.53]	[0.52]
LF	0.462**	1.263	−0.086	−0.151
	[0.00]	[0.17]	[0.20]	[0.58]
AGE	0.006	0.006	−0.017**	−0.017**
	[0.58]	[0.58]	[0.01]	[0.00]
ln(WAGE)	−0.102	−0.118		
	[0.19]	[0.09]		
FGD	−0.102	−0.080	0.057***	0.055***
	[0.31]	[0.40]	[0.00]	[0.00]
POST1991	−0.492***	−0.514***	0.068***	0.067***
	[0.00]	[0.00]	[0.00]	[0.00]
POST1996	−0.612***	−0.572***	−0.001	−0.006
	[0.00]	[0.00]	[0.95]	[0.85]
Constant	2.002	1.251	−6.676***	−6.714***
	[0.18]	[0.24]	[0.00]	[0.00]
N	1718	1718	1923	1923
DV Mean	5.14	5.14	0.06	0.06
Plant FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
1st st. F		4038039.34		2574405.86
R^2	0.94		0.99	

p-values in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is the log of labour or fuel input. The IV estimator is 2-stage least squares within. The estimates for POST1991 and POST1996 are the treatment effects for privatisation and competition respectively. Standard errors are clustered at the treatment level (US states and GB).

B. Variable construction

We filled missing values as follows. First, fuel input is derived from CO2. The formula is:

$$kt(Fuel) = kt(CO2) * EF * CF * CV, \tag{5}$$

where CF is a fuel dependent conversion factor, EF an emission factor, and CV is the heat content. kt stands for kilo tonnes. Second, for use in the labour equation only, we derive output from CO2 emissions using generic efficiency measures where plant specific efficiency measures are not available. The formula is:

$$GWh(Supply) = kt(CO2) * EF * Eff, \tag{6}$$

where EF is the emissions factor, Eff is thermal efficiency.